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Research Article

Accuracy of Intraoral Scanner versus Conventional Method for Bolton Ratio Assessment in a Sample of Duhok Population

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Aims :The study aimed to compare the accuracy and reliability of the measurement of the anterior and overall Bolton ratio between plaster models (by silicone impressions) and intraoral scanner (IOS) images (by TRIOS scanner). **Materials and Methods**: Fifty-one patients were selected from the Duhok University College of Dentistry - Prevention, Orthodontic & Pedodontics Department auditors. Their ages ranged between 18 and 35 years. Each one underwent a silicone impression of the jaws to obtain the plaster models and IOS digital images to obtain the digital models. Both records formed the two study groups: the plaster model group (PMG) and the IOS group (IOSG). Measurements (the anterior and overall Bolton's ratio) were made on plaster and IOS digital images. The Bolton ratios were re-measured on 5 samples for each group by the same researcher a month after the first measurement to determine the accuracy of the re-measurement, and the inter-examiner intraclass correlation coefficients (ICCs) were applied. A paired T-test was conducted to compare the two groups and to study the reliability of the measurement. **Results**: When performing the intraclass correlation (ICC), the results showed the reliability of Bolton ratio measurements in the plaster models and IOS digital images (ICC = 0.998, 0.991 respectively). There were no statistically significant differences between the plaster models and IOS groups concerning the anterior Bolton ratio p = 0.999. There were no statistically significant differences between the plaster models and IOS groups concerning the overall Bolton ratio p = 0.971. **Conclusions**: Plaster models (by silicone impressions) or IOS digital images (by TRIOS scanner) can be used in orthodontic diagnosis to measure the Bolton ratio (anterior and overall) with the same accuracy and reliability.

Keywords: Accuracy, Intra-oral scanner, Bolton ratio

INTRODUCTION

The sizes of the upper and lower teeth must be proportional to obtain good occlusion and correct overbite and overjet. [1] The term size discrepancy between the teeth of both jaws was mentioned by Dr. Wayne Bolton in 1958; in addition, his impact on diagnosis and treatment planning was mentioned [2]. Bolton measured the sizes of the teeth (mesiodistal widths) from the first molar to the first molar. [2]. Then, he collected the measured values for the lower jaw and divided them by the values measured for the upper jaw to produce an average value of 91.3 ± 1.91%, which he called the overall ratio. He divided the sizes of the lower anterior teeth (from canine to canine) by their upper ones to produce an average value of 77.2 ± 1.65%, called the anterior ratio [2].

This study presented the clinical effect of this mathematical ratio and enabled the practitioners to determine the location of the defect, whether it is located in the posterior or anterior region[3]. The Bolton ratio was calculated on plaster models extracted from traditional impressions. Many negative aspects associated with this technique began to appear, as there are errors related to choosing the appropriate impression material or related to recording the impression and its multiplicity of stages, and errors related to casting it, in addition to volumetric changes in the impression, or the expansion of the plaster used to cast it. as well as the difficulty of storing and archiving plaster models and the long time to record and pour it. All these problems stimulated efforts to avoid them and to find a suitable alternative for them[4-6].

In the 1970s, Dr. Duret had a new patent - regarding optical impression through computer-aided design and computer-aided manufacturing technology (CAD / CAM)- a gateway to digital dentistry[7]. In the eighties of the last century, Dr. Mörmann and Marco Brandestini introduced the first intraoral scanner, and this is what established the Chair-side Economical Restoration of Esthetic Ceramic system (CERECs), which later became a trademark in 1987[8-10]. As a result, companies began competing to develop devices, technologies, and software, which reflected positively on practitioners, patients, and the quality of laboratory work[9].

A review of the literature shows that only 3 studies [11-13] have tested the accuracy of intraoral scanners (IOS)in orthodontics and the Calculation of Bolton ratios as an objective.

This study aims to evaluate the accuracy and reliability of the intraoral scanner images (by TRIOS scanner) compared with plaster models (by silicone impressions) in calculating the Bolton ratios (anterior and overall) for a sample from Duhok in the Kurdistan Region. The Null Hypothesis of the study is that there is no difference

between Bolton Ratios (anterior and overall) extracted from IOS digital images (by TRIOS scanner) and those obtained from the plaster models (by silicone impressions).

MATERIALS AND METHODS

Study design and setting

This study was a two-arm(groups) conducted at the Departments of Prevention, Orthodontic & Pedodontics at Duhok University between October 2021 and November 2022. The Local Research Ethics Committee Approval was obtained from the Directorate of Health in Duhok governorate, Ministry of Health, Kurdistan Region (ID=21082022-6-8).

Sample size calculation

The present sample size was calculated using the G×power 3.1.9.4 software (Universität Düsseldorf, Düsseldorf, Germany) based on a significance level of 0.05 and a power of 90%. The smallest difference requiring detection in the mesiodistal width of a tooth was assumed to be 0.125 mm with a standard deviation of 0.268mm (from a previous study [12]); therefore, each group required a sample size of 51 patients. Informed consent was obtained for each patient.

The inclusion criteria are:

1. Age between 18 and 35 years.

2. Full permanent dentition from right first molar to left first molar in both upper and lower arches.

3. Participants should not be under orthodontic treatment.

The exclusion criteria are:

1. Tooth agenesis or extractions.
2. Presence of large restorations that could change the mesiodistal diameters of the teeth.
3. Teeth with anomalous shapes.
4. Teeth with large carious lesions.
5. Enamel defects that affect the morphology of the crown.
6. Severe crowding in the dentition (> 6 mm).
7. Missing teeth.

Based on the previous criteria, the total number of patients participating in the study was 51 patients (19 females and 32 males) with a mean age of 24.38 ±1.05 years.

Sample preparation

All patients participating in the research underwent scaling and polishing before any procedure was performed.

1. For plaster models:

Impressions of the upper and lower arch have been made using C-silicone impression material (putty+light) (Zetaplus, Zhermack, Italy) (Figure 1).

Figure (1): Silicone Impression Recording

Models have been made using orthodontic stone class III (Orthokal, Kalabhi®, Gujarat, India). Models pouring has been done within 1 hour.

2. For Intraoral Images:

The patient's teeth were dried with an air syringe and scanned with the Intraoral scanner (Trios®,3Shape dental systems, Copenhagen, Denmark), as shown in (**Figure 2)**. Scanning was performed for each jaw separately using the strategy shown in (**Figure 3)**.

Figure (2): Take an IOS image

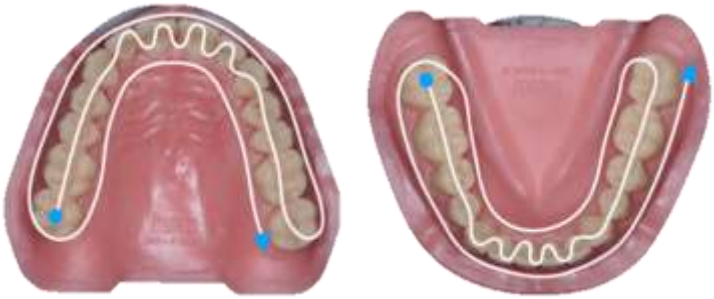

Figure (3): Scan Strategy for Upper and Lower Jaw – Copy

After scanning, the images were opened and the dimensions were measured by Ortho Analyzer® software (3Shape®, Copenhagen, Denmark) on a personal computer.

In this way, 2 groups are formed (plaster models Group (PMG) and Intraoral scanner group (IOSG) to take measurements of teeth widths and the Bolton ratio for each of them.

Measurement of Tooth Widths

1. Plaster models:

On the plaster models, the measurements were done using a digital electronic caliper (Fisher Scientific International Inc., Hampton, NH, USA), and the measurements have been recorded to the nearest 0.01 mm by the examiner. At each tooth's greatest width, the mesiodistal width has been measured by holding the calipers parallel to the occlusal plane of the tooth [(14)]. This has been done from the first right molar to the first left molar for both the maxillary and mandibular models (**Figure 4**).

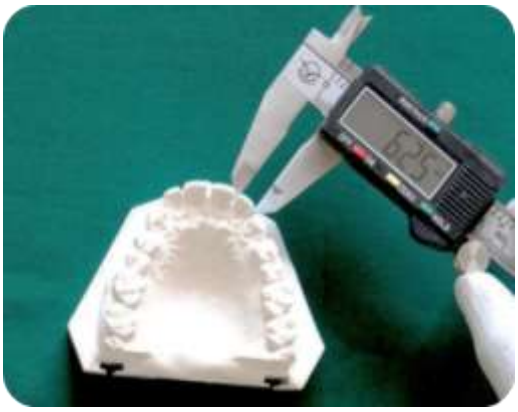

Figure (4): Measuring the width of the teeth on the plaster model

2. Intraoral Digital Images:

Digital images were uploaded to the Ortho Analyzer® software, and teeth widths were measured using the "Diagnostics" tool. To allow proper visualization of each tooth, the program's zoom, rotation, and panning features were fully utilized. Fourteen-inch computer screens with a resolution of 1366×768 pixels and 32-bit color along with a standard computer mouse have been used to manipulate the models and mark points.

Teeth widths have been measured by selecting the maximum mesiodistal width of each crown (**Figure 5**). This has been defined as the distance between the anatomic contact areas when the teeth were correctly aligned. In addition, measurements have been made parallel to the occlusal and labial/buccal surfaces[(13)].

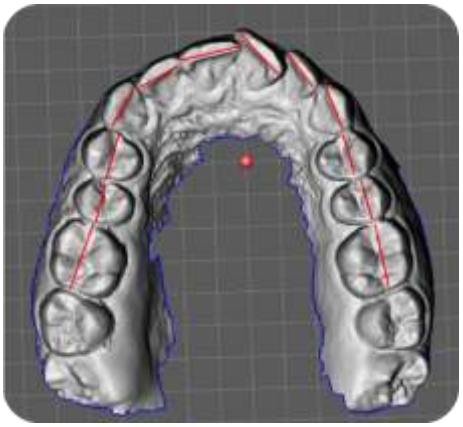

Figure (5): Measuring the width of the teeth on the digital model (from Intraoral Scanner)

Measurement of Bolton's ratios

The Anterior Bolton ratio has been calculated for each patient using Bolton's formula[2]: A sum of the mesiodistal width of mandibular incisors 6 teeth / Sum of the mesiodistal width of maxillary incisors 6 teeth x 100 = Overall ratio (%) in each method (plaster models and intraoral scanner images)

The overall Bolton ratio has been calculated for each patient using Bolton's formula[2]: A sum of the mesiodistal width of mandibular 12 teeth / Sum of the mesiodistal width of maxillary 12 teeth x 100 = Overall ratio (%) in each method (plaster models and intraoral scanner images).

Statistical Analysis

The IBM SPSS Statistics for Windows, v. 20 software (IBM Corp., Armonk, USA) has been used. To analyze the validity, an overall comparison between the two groups was done using a paired T-test with a p-value ≤0.05.

Study of measurement reliability and measurement error:

To assess measurement reliability, five plaster models and 5 intraoral digital images were randomly chosen, and Bolton ratios were remeasured 1 month after the first measurements.

Reliability was evaluated using intraclass correlation (ICC), which gave strong inter-examiner reliability for both plaster models and intraoral scanner images (ICC = 0.998, 0.991 respectively).

RESULTS

The anterior and overall Bolton ratios were calculated from the measured tooth width values for the 51 patients included in this study, and the mean values extracted were very similar to the standard values in Bolton's article.

Table (1) shows the descriptive statistics for the mean of the anterior and overall Bolton values in terms of means, standard deviations, and confidence intervals for each of the study groups (plaster models & IOS digital images).

Table (1): Descriptive Statistics of the Measured Bolton Ratios (AB + OB)

variables	Group	Minimum	Maximum	Mean n=51	SD
AB	**PMG**	71.25	88.27	77.94	3.36
	IOSG	71.35	88.17	77.96	3.34
OB	**PMG**	85.67	96.89	90.09	2.02
	IOSG	85.68	96.99	90.09	2.05

n: Number of patients; SD: standard deviation; PMG: plaster model group; IOSG: intra-oral scan group; AB: Anterior Bolton Ratio; OB: Overall Bolton Ratio

A paired T-test was conducted to study the significance of the differences in the average Bolton ratios (AB+OB) (in mm) between the plaster models group and the IOS group at P≤0.05. The averages of measured **Anterior Bolton ratios** between two groups were compared by using an analysis of variance test (paired T-test) at p≤0.05, there was no significant difference as shown in Table **2.** Also, the averages of measured **Overall Bolton ratios** between two groups were compared using the analysis of variance test (paired T-test) at p≤0.05; there was no significant difference, as shown in Table **3.**

Table (2): Comparison between the groups in the measured Anterior Bolton Ratios (AB)

Bolton Ratios	**PMG** (Gold Standard) **n=51**		**IOSG n=51**		**T Value**	**P Value**
	Mean	SD	Mean	SD		
AB	77.949	3.365	77.969	3.340	0.007	0.99^{ns}

n: Number of patients; SD: standard deviation; PMG: plaster model group; IOSG: intra-oral scan group; AB: Anterior Bolton Ratio; ns: non-significance.

Table (3): Comparison between the groups of the measured Overall Bolton Ratios (OB)

Bolton Ratios	PMG (Gold Standard) n=51		IOSG n=51		T Value	P Value
	Mean	SD	Mean	SD		
OB	90.098	2.026	90.174	2.055	0.023	0.97^{ns}

n: Number of patients; SD: standard deviation; PMG: plaster model group; IOSG: intra-oral scan group; OB: Overall Bolton Ratio; ns: non-significance.

DISCUSSION

The intraoral scan is the latest innovation in dentistry to generate three-dimensional models that can be studied, and many tests were conducted on it to determine its accuracy and reliability by determining tooth widths and the Bolton ratio with the adoption of plaster models or two-dimensional images as a gold standard[15, 16].

This study is the first in the literature comparing the accuracy and reliability of Bolton ratios measurements (anterior and overall) between (TRIOS scanner) and plaster models (by silicone impressions) in a sample of the Duhok population.
Digital images have been uploaded to the Ortho Analyzer® software and tooth widths were measured by marking "set points "and measuring the maximum mesiodistal width. To allow proper visualization of each tooth, the program's zoom, rotation, and panning features were fully utilized[12].

Thus, this method can be closer to the traditional method of measurement, but in a computerized form with some additional digital advantages in terms of zooming in and out, controlling rotation, and making measurements directly on the digital models. Traditionally, the Bolton ratio has been calculated manually from the teeth widths (the mesial/distal width of the teeth) on the plaster model (normal average: AB=77.2 %, OB=91.3%) [2, 3].

In the current study, the average anterior Bolton ratio measured on plaster models was 77.94 %, and the average overall Bolton ratio measured on plaster models was 90.09 %. And the average anterior Bolton ratio measured on IOS digital images was 77.96 %, and the average overall Bolton ratio measured on IOS digital images was 90.17 %. The results showed that there were no significant differences between AB averages between the study groups. When comparing PMG and IOSG, the mean difference was -0.01 mm. According to the study of Akylacin 2011 [17], the largest clinically acceptable error for measuring teeth widths is 0.5 mm, and therefore, the results of these

differences can be considered not statistically significant and have no clinical significance.

The accuracy of the measurement for both anterior and overall Bolton ratios is due to the original accuracy of measuring mean teeth widths.

There is no study in the literature that performed a binary comparison of anterior and overall Bolton ratio measurements using plaster models (by silicone impressions) and IOS digital images (by TRIOS scanner) together in a sample of the Duhok population. The results of the current study agreed with the study of Naidu[13], Wiranto[12], and Camardella[11], where there was no statistical difference compared to the IOS group and the group of plaster models, and the results were statistically and clinically acceptable.

From the above, it can be concluded that there is no difference in statistical and clinical terms regarding Bolton ratio (anterior and overall) whether the values are extracted from TRIOS scanner or plaster model (by silicon impressions)

CONCLUSIONS

Plaster models (by silicon impressions) or IOS digital images (by TRIOS scanner) can be used in orthodontic diagnosis with the same accuracy and reliability regarding both Bolton ratios (anterior and overall).

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Ethical statement: The Local Research Ethics Committee Approval was obtained from the Directorate of Health in Duhok governorate, Ministry of Health, Kurdistan Region (ID=21082022-6-8).

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript

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دقة الماسح داخل الفموي مقارنةً بالطريقة التقليدية لتقييم مُشعر بولتون لعينة من سكان الدهوك

سالار خليل؛ يونس حسن؛ محمد رضوان سرى

الملخص

ألاهداف: تهدف الدراسة لمقارنة دقة وموثوقية قياس مشعر بولتون الأمامي والكلي بين القوالب الجبسية (المستخلصة من قوالب سيليكونية)، وصور الماسح داخل الفموي(المستخلصة من جهاز TRIOS). **المواد وطرائق العمل**: تم جمع 51 مريضاً من جامعة الدهوك - قسم الأطفال والتقويم وطب الأسنان الوقائي - ممن تراوح أعمارهم بين 18 و35 سنة. خضع كل مريض لطبعة سيليكونية لكلا الفكين - للحصول على القوالب الجبسية - ولتصوير بالماسح الفموي لكلا الفكين للحصول على القوالب الرقمية (صور الـــ IOS). تم تقسيم السجلات التشخيصية لمجموعتين: مجموعة القوالب الجبسية ومجموعة الماسح داخل الفموي. تم إجراء قياسات مشعر بولتون الأمامي والكلي على الأمثلة الجبسية وعلى صور الماسح داخل الفموي. تم انتقاء خمس سجلات عشوائياً من كل مجموعة وإجراء إعادة قياس لمشعر بولتون الأمامي والكلي بعد شهر من القياس الأول للتأكد من موثوقية القياس باستخدام معامل الارتباط البيني ICC. كما تم استخدام اختبار T للعينات المترابطة لمقارنة دقة القياسات بين مجموعتي الدراسة. **النتائج**: عند دراسة معامل الارتباط للعينات المُعاد قياسها، لوحظ وجود موثوقية وقابلية تكرار لقياس مشعر بولتون الأمامي والكلي على (ICC=0.999,0.0.991على الترتيب). لم يكن هناك أي فوارق ذات دلالة إحصائية فيما يخص قياسات مشعر بولتون الأمامي بين مجموعتي الدراسة p=0.999. لم يكن هناك أي فارق ذو دلالة إحصائية فيما يخص قياسات مشعر بولتون الكلي بين مجموعتي الدراسة p=0.971. **الاستنتاجات**: يمكن استخدام القوالب الجبسية (المستخلصة من القوالب السيليكونية) والماسح داخل الفموي TRIOSكوسيلة تشخيصية لقياس مشعر بولتون الأمامي والكلي بنفس الدقة والموثوقية.